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Treatment Technology Briefs Alternatives to Hazardous Waste Landfills

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Treatment Technology Briefs

Alternatives to Hazardous Waste Landfills

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The treatment technology processes included in this summary relate to technology which is available and applicable to hazardous waste disposal now. That is, further research is not required for application in the field. What remains is to apply the technology and derive the necessary design parameters and the costs for large-scale application. These derivations require, as a minimum, pilot-scale and more appropriately full-scale application at waste disposal sites and generator locations.

The purpose of making these briefs available is to remind the reader that processes and techniques are available and to encourage a search for additional information. Information in the briefs is not sufficient to permit direct evaluation of a process or technology. For evaluations involving specific sites or waste streams, the reader should consult sources that provide operational, effectiveness, and cost data.

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Introduction

Technologies other than landfill and containment need to be applied in the management of hazardous wastes. Acceptance of treatment technologies other than those currently being used is slow in coming. The Hazardous Solid Waste Act Amendments (HSWA) of 1984 modifying RCRA and the EPA policies of CERCLA cleanups using RCRA requirements at least as guidelines will require new approaches to the problem.

The treatment technology material included in this summary relates to technology which is available and applicable to hazardous waste disposal now. That is, further research is not required for application in the field. What remains is to apply the technology and derive the necessary design parameters and the costs for large-scale application. These derivations require, as a minimum, pilot-scale and more appropriately full-scale application at waste disposal sites and generator locations.

The selections of processes for presentation in this compendium is based on opinions resulting from technical evaluation. The purpose of making these briefs available is to remind the reader that processes and techniques are available and to encourage a search for additional information. Information in the briefs is not sufficient to permit direct evaluation of a process or technology. For evaluations involving specific sites or waste streams, the reader should consult sources that provide operational, effectiveness, and cost data.

Technology: Advanced Biological Methods

Brief Description: Two Processes—(1) Aerobic fluidized bed (suspended sand and oxygen), to provide large surface areas to improve microbial degradation of soluble solids. (2) Membrane aerobic reactor systems prevent loss of cell mass and thereby provide high concentrations of cells to destroy pollutants.

Applicability/Limitation: Process requires predeveloped microbes to be added to treatment systems. Natural microbes have been demonstrated to destroy pollutants in paint sludges.

Status/Availability: Biological systems are available.

Manufacturer: Dorr-Oliver

Users: General Motors

EPA Contact: Charles Rogers, (513) 569-7757

Technology: Aerobic Biological Treatment

Brief Description: Microorganisms metabolize biodegradable organics in aqueous waste. This treatment includes conventional activated sludge processes as well as modifications such as sequencing batch reactors, and aerobic attached growth biological processes such as rotating biological contactors and trickling filters. Aerobic processes are capable of significantly reducing a wide range of organic toxic and hazardous compounds; however, only dilute aqueous wastes (<1%) are normally treatable. Recent developments with genetically engineered bacteria have been reported to be effective for biological treatment of specific hazardous waste which is relatively uniform in composition.

Applicability/Limitation: Used to treat aqueous wastes contaminated with low levels (BOD <10,000 mg/l) of non-halogenated organic and/or certain halogenated organics. The treatment requires consistent, stable operating conditions.

Design Criteria: There are numerous variations of the activated sludge process, however, fundamentally the principles of the unit operations are the same. The first step in the process involves aeration in an open tank, in which the organic biodegradable matter in the waste is degraded by microorganisms in the presence of oxygen. The hydraulic detention time of this unit operation is usually from 6 to 24 hours, although depending on the process mode, shorter or longer detection times may be incorporated. This is followed by a sludge-liquid separation step in a clarifier. Organic loading rates can vary from 10 to 180 lbs of BOD applied per 1000 ft^3 depending on the MLSS concentration, the F/M ratio, and oxygen supply. Variations of the conventional activated sludge system that incorporate pure oxygen or powdered activated carbon have reported excellent pollutant removals for typically difficult to treat waste.

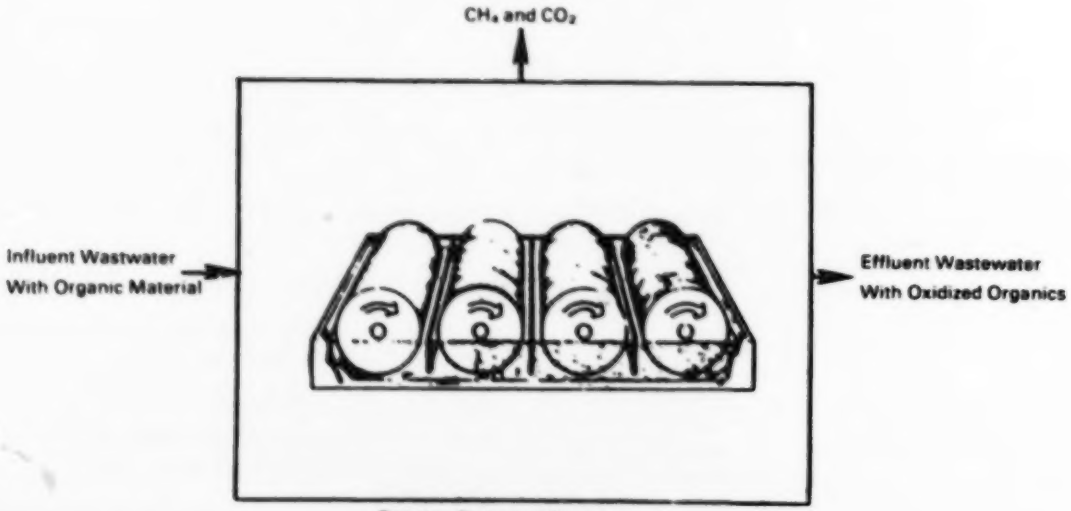
Status/Availability: Commercially available.

Manufacturer: Polybac Corporation, Mike Cawthray
Detox, Inc., Evan K. Nyer (fixed film), (513) 433-7394
Ground Decontamination Systems, Joe Mahan, (201) 265-6727

Users: OH Materials, Joe Kirk, (219) 423-3526

EPA Contact: Ron Turner, (513) 569-7775

Schematic of rotating biological contactor.



Rotating Biological Contactor
(Courtest of Envirex)

Technology: Air Stripping

Brief Description: Air stripping is a mass transfer process in which volatile contaminants in water or soil are transferred to air. Design considerations—factors important in removal or organics from wastewater in air stripping are temperature, pressure, air-to-water ratio, and surface area available for mass transfer. A packed tower air stripper is shown on the next page. Practical tower diameters range from 1 to 12 ft with packing heights as high as 50 ft, air-to-water volumetric ratios may range from 10 to 1 up to 300 to 1. The resulting residuals are the contaminated off-gas and the "stripped" effluent.

Applicability/Limitation: Used to treat aqueous organic wastes with relatively high volatility, low water solubility (e.g., chlorinated hydrocarbons such as tetrachloroethylene, and aromatics such as toluene). Limitations include concentrations of VOCs less than 100 ppm, temperature dependence and the presence of suspended solids.

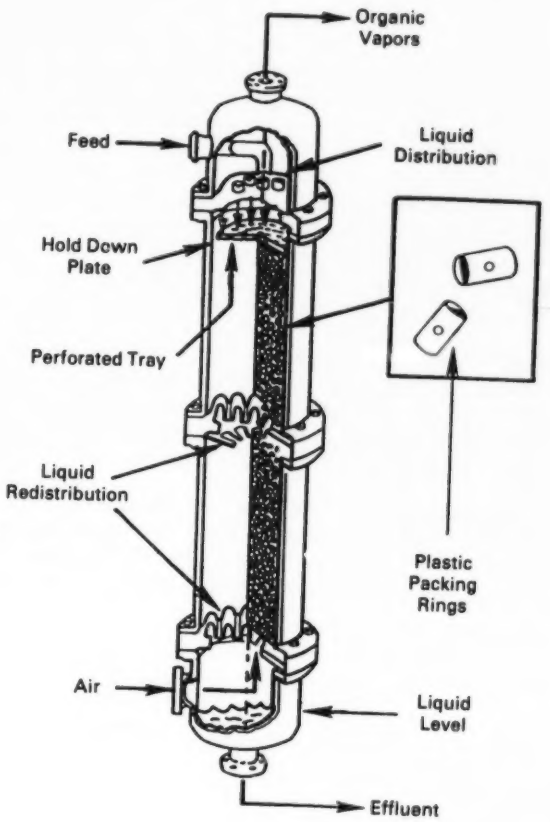
Status/Availability: Commercially available.

Manufacturer: See buyer's guides from trade journals.

Users: Superfund Sites: Triangle Chemical, McKin site and Verona Wellfield

EPA Contact: Ron Turner, (513) 569-7775

Schematic of air stripping.



Technology: Alkali Metal Dechlorination

Brief Description: Several chemical dechlorination processes are based on a method developed by the Goodyear Tire and Rubber Company in 1980. The original method uses sodium plus naphthalene in tetrahydrofuran (that is, sodium naphthalide) to strip chlorine atoms from PCBs resulting in polymerizing the biphenyl into inert condensible sludge. The reactor is blanketed with nitrogen and an excess of reagent to chlorine content is required. The Goodyear Company has not commercially developed the technology. However, several companies have modified the method by substituting their own proprietary reagent for the naphthalene. The equipment is mobile and can be transported on semitrailers.

Applicability/Limitation: Used to treat PCBs, chlorinated hydrocarbons, acids, thiols, chlorides and dioxins. Moisture content adversely affects rates of reactions.

Status/Availability: Commercially available.

Manufacturer: American Mobile Purification, Peter Lawson-Johnson, (212) 267-7073
SunOhio, Doug Toman, (216) 452-0837
PPM, Inc., (404) 934-0902
Acurex, Jim Thompson, (415) 964-3200
Chemical Waste Management, Peter Daily, (312) 841-8360
Exceltech, Inc., John Sedwick, (415) 659-0404

EPA Contact: Charles Rogers, (513) 569-7757

Technology: Alkali Metal/Polyethylene Glycol (PEG)

Brief Description: In 1978 the EPA sponsored research which led to the development of the first of a series of A/PEG reagents which were shown to effectively dechlorinate PCBs in oils. Essentially, these reagents were alkali metal polyethylene glycolates which react rapidly to dehalogenate haloorganic compounds of all types under ambient and high temperature conditions. In the A/PEG reagents, the alkali metal ion is held in solution by the large polyethylene glycolate anion. PCBs and other halogenated molecules are uniquely soluble in A/PEG reagents. These qualities combine to give a single-phase system in which the high concentration of anions readily displaces the halogen atoms on halogenated molecules. The reaction of halogenated aromatics with PEGs results in a substitution of the PEG for the chlorine atom to form a PEG ether. The PEG ether, in turn, may then decompose to a phenol. The biotoxicity of reaction by-products is under investigation.

Applicability/Limitation: Heat and excess reagent are required for the process to function effectively in soils containing more than seven percent moisture.

Status/Availability: Laboratory scale. Ready for field test.

EPA Contact: Charles Rogers, (513) 569-7757.

Technology: Alkaline Chlorination

Brief Description: In this process, chlorine gas (with caustic), chlorine dioxide, or hypochlorite (sodium or calcium) are routinely used to destroy cyanide which is converted to nitrogen gas and carbon dioxide gas.

Applicability/Limitation: Used to treat free cyanides and complex cyanides although combinations with Fe or Ni will take a longer time. Limitations include the exothermic heat of the reaeration, pH, non-selective competitions with other species and additional chlorine demands. Fairly close pH control (7.5 to 9.0) required to avoid toxic volatiles release. Reduction efficiency about 99.6 percent.

Status/Availability: Generally available.

Manufacturer: See buyer's guides in trade journals.

Users: Electroplating industry.

EPA Contact: S. Garry Howell, (513) 569-7756.

Technology: Anaerobic Biological Treatments

Brief Description: The anaerobic biological treatment process encompasses the reduction of organic matter in an oxygen-free environment to methane and carbon dioxide. The most common anaerobic attached growth treatment process is the anaerobic filter. This process consists of a column filled with solid media. A number of proprietary anaerobic biotechnology processes are actively being marketed, each with distinct features, but all utilizing the fundamental anaerobic conversion to methane.

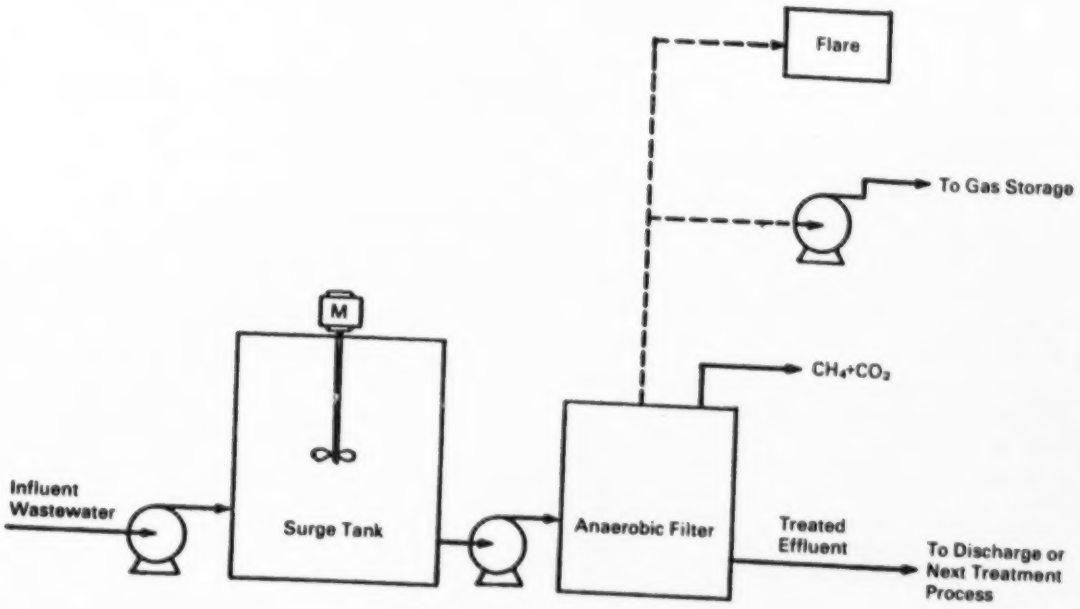
Applicability/Limitation: Used to treat aqueous wastes with low to moderate levels of organics. Anaerobic digestion can handle certain halogenated organics better than aerobic treatment. Stable, consistent operating conditions must be maintained. Anaerobic degradation can take place in native soils but when used as a controlled treatment process, an air tight reactor is required. Hazardous organic substances that have been found to be amenable to anaerobic treatment include acetaldehyde, acetic anhydride, acetone, acrylic acid, aniline, benzoic acid, butanol, cresol, ethyl acrylate, MEK, phenol and vinyl acetate.

Status/Availability: No mobile units are available. Current, state-of-the-art processes available.

Manufacturer: FMC, GDS and several other providers of selected microbes, nutrients, or systems designs.

EPA Contact: Ronald Lewis, (513) 569-7856.

Schematic of anaerobic filter system.



Technology: Asphalt-Based Stabilization/ Solidification (Thermoplastic Microencapsulation)

Brief Description: Involves the mixing of heated, dried wastes within either an asphalt bitumen, paraffin or polyethylene matrix resulting in a solid waste mass for landfill disposal. The advantages are waste volume reduction, low impermeability, elimination of free liquid, improved handling and good strength.

Applicability/Limitation: This method is applicable to hazardous wastes that are complex and difficult to treat. Wastes that should not be treated using this technology are: wastes with high water content; strongly oxidizing contaminants; anhydrous inorganic salts; tetraborates; iron and aluminum salts; and organics with low molecular weights and high vapor pressures (volatile). The disadvantages include expensive equipment, high processing cost and air pollution potential.

Status/Availability: Commercially available.

Manufacturer: Werner A. Pfleidier, Waldick, New Jersey
Aerojet Energy Conversion Company, Sacramento, California
Newport News Industrial Corporation, Newport News, Virginia

Users: _____

EPA Contact: Robert Landreth, (513) 569-7836.

Technology: Blast Furnaces (Iron and Steel)

Brief Description: Blast furnace temperatures may reach up to 3400°F, and are generally above 3000°F. High heat content hazardous wastes can be used to supplement coke and other fuel requirements for blast furnace. A blast furnace produces molten iron from iron ore and other iron bearing feed materials. Iron ore, carbon (coke) and limestone feed to the top of the furnace and iron product and slag are removed in different layers from the bottom. HWF can be injected just above slag layer.

Applicability/Limitation: Composition (trace elements) of HWF must be controlled to avoid product quality problems. Waste oils were fired into blast furnace in HWERL test programs.

Status/Availability: Less than 80 blast furnaces currently operating in U.S.

Manufacturer: Several—Must be field constructed.

Users: Cadence Chemicals, Mike Benoit, (219) 879-0371

EPA Contact: Robert Mournighan, (513) 569-7408

Technology: Carbon Adsorption

Brief Description: Removes dissolved organics from aqueous wastes, and organics from air streams due to the surface attachment between organic solutes and the large internal pore surface area of activated carbon grains. The residuals are spent carbon and regenerant (steam or solvent).

Applicability/Limitation: Used to treat single-phase aqueous organic wastes with high molecular weight and boiling point and *low solubility* and *polarity*, chlorinated hydrocarbons such as tetrachloroethylene, and aromatics such as phenol. Limitations are organic contaminant concentrations <10,000 ppm, suspended solids <50 ppm, dissolved inorganics and oil and grease <10 ppm.

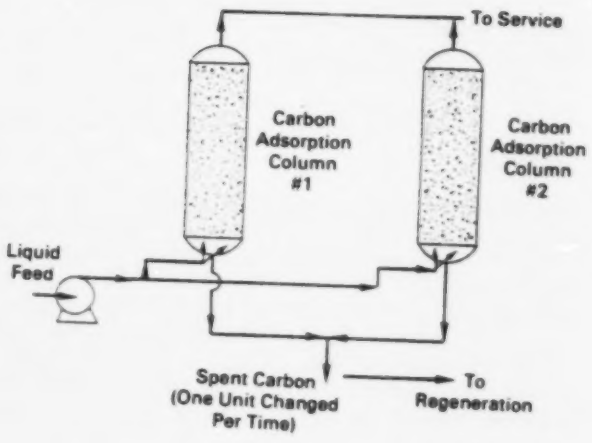
Status/Availability: EPA Environmental Emergency Response Unit—two transportable systems (50-gpm and 600-gpm units).

Manufacturer: Calgon Carbon Corporation, Dave Jordan, (201) 526-4646
Carbon Air Services, Inc., (612) 935-1844
Zimpro, Inc., (715) 359-7211
Chemical Waste Management, John Fink, (714) 940-7971

Users: IT Corporation, California

EPA Contact: Ron Turner, (513) 569-7775
Richard Traver, (201) 321-6677

Schematic of carbon adsorption.



Toxic Compounds Removed from Water Using the Carbon Adsorption System in the Hazardous Material Spills Treatment Trailer

Compound	Location of Incident	Quantity Treated (gallons)	Contact Time (minutes)	Influent Concentration (ppb)	Effluent Concentration (ppb)	Percent Removal
DNBP	Clarksburgh, New Jersey	2,000,000	26	8	<.002	99.98
PCB	Seattle, Washington	600,000	30-40	400	<.075	99.98*
Toxaphene	The Plains, Virginia	250,000	26	38	1	97.22
Chlordane	Strongstown, Pennsylvania	100,000	17	13	.35	97.3
		3,000	240	1,430	.43	99.99
Heptachlor	Strongstown, Pennsylvania	100,000	17	6.1	.06	99.02
		3,000	240	80	.1	99.87
Aldrin	Strongstown, Pennsylvania	100,000	17	8.5	.19	97.76
		3,000	240	60.5	.15	99.75
Dieldrin	Strongstown, Pennsylvania	100,000	17	11	<.01	99.99*
		3,000	240	60.5	<.01	99.99*
Kepone	Hopewell, Virginia	225,000	45.5	4,000	<1	99.98
Pentachlorophenol	Haverford, Pennsylvania	215,000	26	10,000	<1	99.98

Toxic Compounds Removed from Water Using the Carbon Adsorption System in the Hazardous Material Spills Treatment Trailer (Continued)

Compound	Location of Incident	Quantity Treated (gallons)	Contact Time (minutes)	Influent Concentration (ppb)	Effluent Concentration (ppb)	Percent Removal
Methylene Chloride	Oswego, New York	250,000	8.5	190	51	73.15
Carbon Tetrachloride	Oswego, New York	250,000	8.5	1.1	<1	90.91*
Benzene	Oswego, New York	250,000	8.5	1	.1	90
Toluene	Oswego, New York	250,000	8.5	120	.3	99.75
Xylene	Oswego, New York	250,000	8.5	140	<1	99.92*
Trichloroethane	Oswego, New York	250,000	8.5	12	<1	99.17*
Trichloroethylene	Oswego, New York	250,000	8.5	21	.3	98.57

Source: Becker, D. L., S. C. Wilson, 1978.

Amenability of Typical Organic Compounds to Activated Carbon Adsorption

Compound	Molecular Weight	Aqueous Solubility (%)	Concentration mg/l Initial (C_o)	Concentration mg/l Final (C_f)	Adsorbability % compound/ % carbon	Adsorbability Percent Reduction
Alcohols						
Methanol	32.0	-	1,000	964	0.007	3.6
Ethanol	46.1	-	1,000	901	0.020	10.0
Propanol	60.1	-	1,000	811	0.038	18.9
Butanol	74.1	7.7	1,000	466	0.107	53.4
n-Amyl alcohol	88.2	1.7	1,000	282	0.155	71.8
n-Hexanol	102.2	0.58	1,000	45	0.191	95.5
Isopropanol	60.1	-	1,000	874	0.025	12.6
Allyl alcohol	58.1	-	1,010	789	0.024	21.9
Isobutanol	74.1	8.5	1,000	581	0.084	41.9
t-Butanol	74.1	-	1,000	705	0.059	29.5
2-Ethyl butanol	102.2	0.43	1,000	145	0.170	85.5
2-Ethyl hexanol	130.2	0.07	700	10	0.138	98.5
Aldehydes						
Formaldehyde	30.0	-	1,000	908	0.018	9.2
Acetaldehyde	44.1	-	1,000	881	0.022	11.9
Propionaldehyde	58.1	22	1,000	723	0.057	27.7
Butyraldehyde	72.1	7.1	1,000	472	0.106	52.8
Acrolein	56.1	20.6	1,000	694	0.061	30.6
Crotonaldehyde	70.1	15.5	1,000	544	0.092	45.6
Benzaldehyde	106.1	0.33	1,000	60	0.188	94.0
Paraldehyde	132.2	10.5	1,000	261	0.148	73.9
Amines						
Di-N-Propylamine	101.2	-	1,000	198	0.174	80.2
Butylamine	73.1	-	1,000	480	0.103	52.0
Di-N-Butylamine	129.3	-	1,000	130	0.174	87.0
Allylamine	57.1	-	1,000	686	0.063	31.4
Ethylenediamine	60.1	-	1,000	893	0.021	10.7
Diethylenetriamine	103.2	-	1,000	706	0.062	29.4
Monethanolamine	61.1	-	1,012	939	0.015	7.2
Diethanolamine	105.1	95.4	996	722	0.057	27.5
Triethanolamine	149.1	-	1,000	670	0.067	33.0
Monoisopropanolamine	75.1	-	1,000	800	0.040	20.0
Diisopropanolamine	133.2	87	1,000	543	0.091	45.7
Pyridines & Morpholines						
Pyridine	79.1	-	1,000	527	0.095	47.3
2-Methyl-5-ethyl pyridine	121.2	sl. sol.	1,000	107	0.179	89.3
N-Methyl morpholine	101.2	-	1,000	575	0.085	42.5
N-Ethyl morpholine	115.2	-	1,000	467	0.107	53.3

Amenability of Typical Organic Compounds to Activated Carbon Adsorption (Continued)

Compound	Molecular Weight	Aqueous Solubility (%)	Concentration mg/l Initial (C_o)	Concentration mg/l Final (C_f)	Adsorbability % compound/ % carbon	Adsorbability Percent Reduction
Aromatics						
Benzene	78.1	0.07	416	21	0.080	95.0
Toluene	92.1	0.047	317	66	0.050	79.2
Ethyl benzene	106.2	0.02	115	18	0.019	84.3
Phenol	94	6.7	1,000	194	0.161	80.6
Hydroquinone	110.1	6.0	1,000	167	0.167	83.3
Aniline	93.1	3.4	1,000	251	0.150	74.9
Styrene	104.2	0.03	180	18	0.028	88.8
Nitrobenzene	123.1	0.19	1,023	44	0.196	95.6
Esters						
Methyl acetate	74.1	31.9	1,030	760	0.054	26.2
Ethyl acetate	88.1	8.7	1,000	495	0.100	50.5
Propylacetate	102.1	2	1,000	248	0.149	75.2
Butyl acetate	116.2	0.68	1,000	154	0.169	84.6
Primary amyl acetate	130.2	0.2	985	119	0.175	88.0
Isopropyl acetate	102.1	2.9	1,000	319	0.137	68.1
Isobutyl acetate	116.2	0.63	1,000	180	0.164	82.0
Vinyl acetate	86.1	2.8	1,000	357	0.129	64.3
Ethylene glycol monoethyl ether acetate	132.2	22.9	1,000	342	0.132	65.8
Ethyl acrylate	100.1	2.0	1,015	226	0.157	77.7
Butyl acrylate	128.2	0.2	1,000	43	0.193	95.9
Ethers						
Isopropyl ether	102.2	1.2	1,023	203	0.162	80.0
Butyl ether	130.2	0.03	197	nil	0.039	100.0
Dichloroisopropylene ether	171.1	0.17	1,008	nil	0.200	100.0
Glycols & Glycol Ethers						
Ethylene glycol	62.1	-	1,000	932	0.0136	6.8
Diethylene glycol	106.1	-	1,000	738	0.053	26.2
Triethylene glycol	150.2	-	1,000	477	0.105	52.3
Tetraethylene glycol	194.2	-	1,000	419	0.116	58.1
Propylene glycol	76.1	-	1,000	884	0.024	11.6
Dipropylene glycol	134.2	-	1,000	835	0.033	16.5
Hexylene glycol	118.2	-	1,000	386	0.122	61.4
Ethylene glycol monomethyl ether	76.1	-	1,024	886	0.028	13.5
Ethylene glycol monoethyl ether	90.1	-	1,022	705	0.063	31.0
Ethylene glycol monobutyl ether	118.2	-	1,000	441	0.112	55.9
Ethylene glycol monohexyl ether	146.2	0.99	975	126	0.170	87.1
Diethylene glycol monoethyl ether	134.2	-	1,010	570	0.087	43.6
Diethylene glycol monobutyl ether	162.2	-	1,000	173	0.166	82.7
Ethoxytriglycol	178.2	-	1,000	303	0.139	69.7
Halogenated						
Ethylene dichloride	99.0	0.81	1,000	189	0.163	81.1
Propylene dichloride	113.0	0.30	1,000	71	0.183	92.9
Ketones						
Acetone	58.1	-	1,000	782	0.043	21.8
Methylethyl ketone	72.1	26.8	1,000	532	0.094	46.8
Methyl propyl ketone	86.1	4.3	1,000	305	0.139	69.5
Methyl butyl ketone	100.2	v. sl. sol	988	191	0.159	80.7
Methyl isobutyl ketone	100.2	1.9	1,000	152	0.169	84.8
Methyl isoamyl ketone	114.2	0.54	986	146	0.169	85.2
Diisobutyl ketone	142.2	0.05	300	nil	0.060	100.0
Cyclohexanone	98.2	2.5	1,000	332	0.134	66.8
Acetophenone	120.1	0.55	1,000	28	0.194	97.2
Isophorone	138.2	1.2	1,000	34	0.193	96.6
Organic Acids						
Formic acid	46.0	-	1,000	765	0.047	23.5
Acetic acid	60.1	-	1,000	760	0.048	24.0
Propionic acid	74.1	-	1,000	674	0.065	32.6
Butyric acid	88.1	-	1,000	405	0.119	59.5
Valeric acid	102.1	2.4	1,000	203	0.159	79.7
Caproic acid	116.2	1.1	1,000	30	0.194	97.0
Acrylic acid	72.1	-	1,000	355	0.129	64.5
Benzoic acid	12.1	0.29	1,000	89	0.183	91.1
Oxides						
Propylene oxide	58.1	40.5	1,000	739	0.052	26.1
Styrene oxide	120.2	0.3	1,000	47	0.190	95.3

Technology: Catalytic Dehydrochlorination

Brief Description: Catalytic dehydrochlorination is based on the reaction of polychlorinated hydrocarbons with high-pressure hydrogen gas in the presence of a catalyst. The feed must be in either liquid or gaseous form with the inorganic and inert constituents removed. The choice of catalyst depends on the process requirements. The operating temperatures are 671° to 707°F under 30 to 50 atms pressure. The quantity of catalyst (usually 61 percent Ni on Kieselguher or 10 percent palladium in C for PCB compounds) is about 0.2 percent of pollutant weight.

Applicability/Limitation: In general, supported catalysts are quickly deactivated by impurities such as tars, sulfur compounds, etc. These processes are excessively costly and often require the use of hazardous chemicals.

Status/Availability: Laboratory scale.

Manufacturer: _____

Users: _____

EPA Contact: Charles Rogers, (513) 569-7757

Technology: Centrifugation

Brief Description: Centrifugation is a physical separation process in which the components of a fluid mixture are separated mechanically, based on their density, by rapidly rotating the mass of fluid within a rigid vessel. Centripetal forces in centrifugation are similar to gravitational forces in sedimentation except that centripetal forces are thousands of times stronger than gravitational forces, depending on diameter and rotational speed of the centrifuge.

Applicability/Limitation: Dewatering, separating oil and water, clarification of viscous gums and resins, and recovery of metals. Centrifuges are generally better suited than vacuum filters for dewatering sticky or gelatinous sludges. Disc-type centrifuges can be used to separate a three-component mixture (i.e., oil, water, solids). Centrifuges cannot generally be used for clarification since they may fail to remove solids which are not large or dense particles. Recovery and removal efficiencies may be improved if filter paper or cloth are incorporated in the centrifuges.

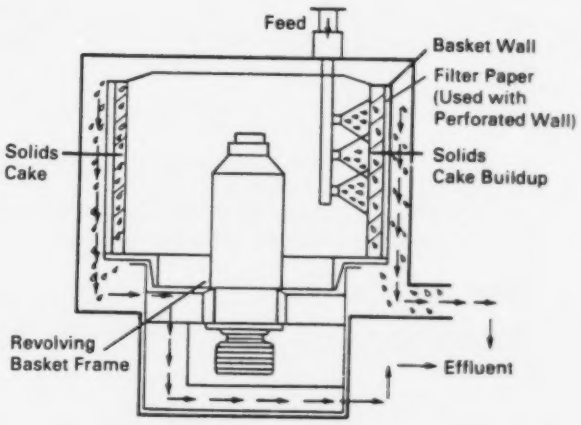
Status/Availability: Commercially available.

Manufacturer: Western States Machine
Bird, Fletcher
Sharples
Dorr-Oliver

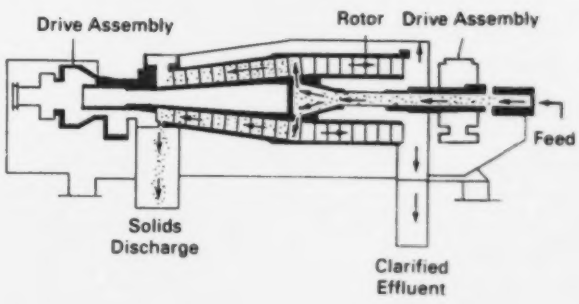
Users: Widespread

EPA Contact: S. Garry Howell, (513) 569-7756

Basket centrifuge.



Solid bowl centrifuge.



Technology: Chemical Precipitation

Brief Description: Chemical precipitation facilities remove dissolved metals from aqueous wastes by chemically converting the metals into insoluble form. Metals may be precipitated from solution as hydroxides, sulfides, carbonates or other salts. Hydroxide precipitation with lime is most common; however, sodium sulfide is sometimes used to achieve lower effluent metal concentrations. This involves pH adjustment followed by sodium sulfide and flocculant aid additions. Solids separation is effected by standard flocculation coagulation techniques. The resulting residuals are metal sludge and the treated effluent with an elevated pH and, in the case of sulfide precipitation, excess sulfide.

Applicability/Limitation: This technology is used to treat aqueous wastes containing metals including: zinc, arsenic, copper, manganese, mercury, cadmium, trivalent chromium, lead and nickel. Selective precipitation of barium as barium sulfate and silver as silver chloride are other applications. Limitations include optimum pH for the mix of metals present and chelating or complexing agents. Organics are not removed. The resulting sludge may be hazardous by definition but often may be delisted by specific petition. Sulfide precipitation has been successfully used at a plating facility (as shown in the following table).

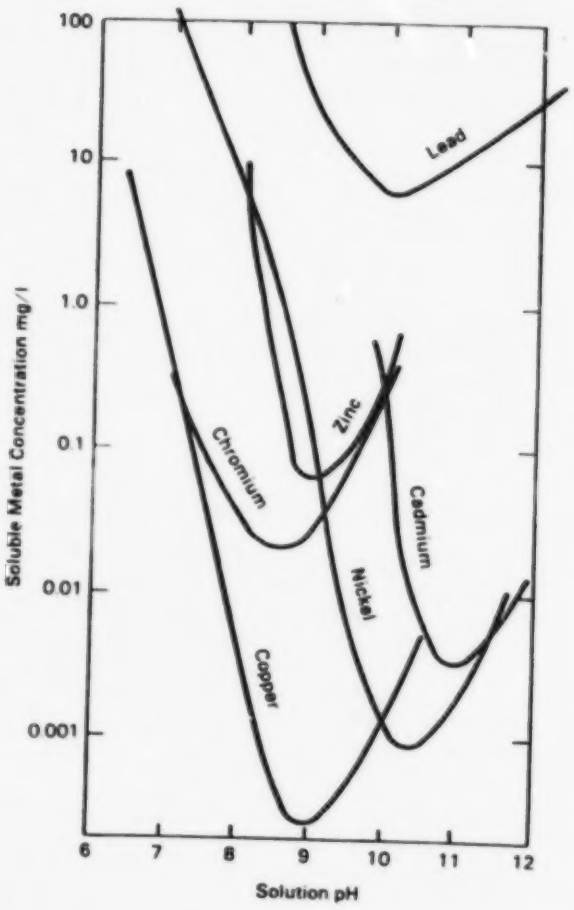
Status/Availability: Commercially available.

Manufacturer: Mobile Systems—Rexnord CRIG, Richard Ostawski, (414) 643-2762
Ecolochem, Inc., Richard Smallwood, (800) 446-8004
Dravo Corporation, Ogden Clemons, (412) 777-5235

Users: Widespread

EPA Contact: S. Garry Howell, (513) 569-7756

Solubilities of metal hydroxides as a function of pH.



Treatment of Industrial Plating Wastewaters by Sulfide Precipitation and Settling

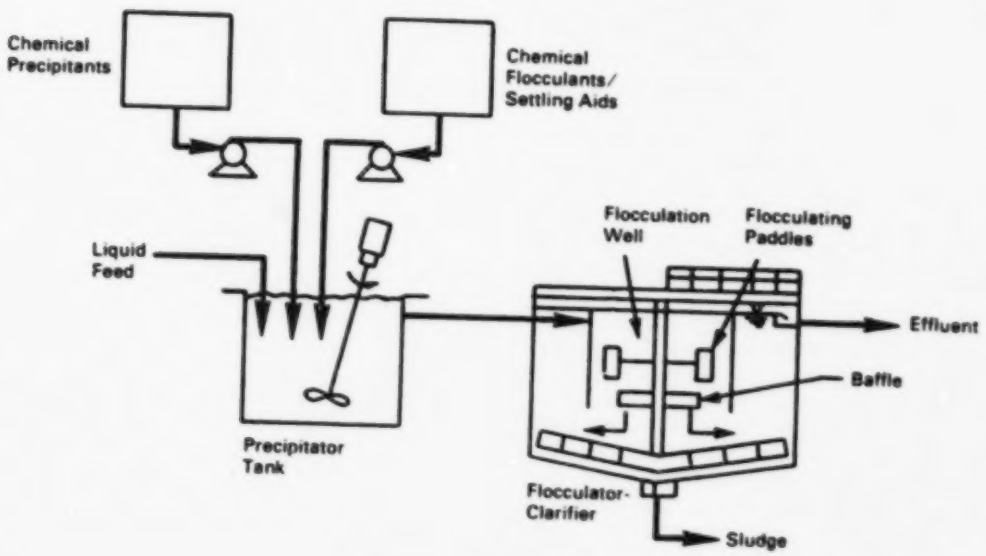
Initial conditions of wastewater:

pH = 7.1 ± 0.1
Zn = 82.7 mg/l = 1.264 mM
Ni = 4.7 mg/l = 0.080 mM
Total Metals = 1.344 mM

Run No.	pH	t, min	S" Dosage	Residual Metal, mg/l		Removal Efficiency, %		
				Zn	Ni	Zn	Ni	Overall
35	10.0	10.0	1.15x	5.0	0.04	<93.95	99.15	<94.34
36	10.0	10.0	0	3.4	0.05	95.89	98.94	96.15
37	10.0	15.0	1.15x	4.4	0.11	94.68	97.66	94.94
38	10.0	15.0	0	>5.0	0.08	<93.95	98.30	<94.29
39	10.0	5.0	1.15x	0.76	0.15	99.08	96.81	99.03
40	10.0	5.0	0	3.6	0.09	95.65	98.09	95.87
41	10.0	10.0	1.0x	4.7	0.10	94.32	97.87	94.61
42	10.0	10.0	0.8x	>5.0	0.20	<93.95	95.74	<94.41
43	7.2	10.0	0.8x	>5.0	1.05	<93.95	77.66	93.06
44	7.4	10.0	1.15x	>5.0	>5.0	<93.95	0	88.44

Ref: Peters, 1984.

Chemical precipitation and associated process steps.



Technology: Circulating Bed Combustor

Brief Description: The GA circulating bed combustor is designed to be an improvement over conventional fluidized beds. The system operates at higher velocities and with finer sorbents than fluidized bed systems. This permits a unit that is more compact and easier to feed. The unit also produces lower emissions and uses less sorbent materials than the fluidized bed systems. No off-gas scrubber is necessary in the circulating bed combustor and heat can be recovered as an added benefit.

The key to the high efficiency of the circulating bed combustor is the high turbulence that is achieved within the combustor. This feature allows efficient destruction of all types of halogenated hydrocarbons, including BCBs and other aromatics, at relatively low temperatures (less than 850°C). All acid gases are captured within the combustion chamber by injected limestone. Compounds containing high levels of phosphorus, sulfur, cyanide, etc., can be processed with emissions of NO_x, CO and acid gases. In addition to the turbulence a large combustion zone with uniform (and lower) temperature throughout also contributes to high efficiency. The circulating bed combustor also features longer residence times of the combustibles and sorbents in the combustion zone.

Applicability/Limitation: The system is capable of treating solids, sludges, slurries and liquids containing such compounds as chlorobenzenes, acetonitrile, carbon tetrachloride, trichloroethane, sodium fluoride, tributyl phosphate, aniline, malathion, sodium silicates and lead oxide.

The system is capable of handling feeds of liquids, sludges or solids. The process requires no atomizer or multiple feed ports for successful treatment. The high degree of turbulence and mixing ensures treatment of a wide variety of wastes. The wastes however must be homogenous in composition when fed to the combustor.

An additional benefit of the circulating bed incinerator is the possibility of heat recovery. Energy can be recovered either as steam or hot water. The system takes advantage of good heat transfer in the combustor rather than utilizing a separate waste heat boiler for heat recovery. This is possible because the combustion chamber is of "water wall" construction, therefore, cooling tubes need not be located in the direct path of hot gases.

Status/Availability: Ready for field-scale testing.

Manufacturer: G. A. Technologies

Users: _____

EPA Contact: Donald Oberacker, (513) 569-7341

Technology: Circulating Bed Combustor

Brief Description: The GA circulating bed combustor is designed to be an improvement over conventional fluidized beds. The system operates at higher velocities and with finer sorbents than fluidized bed systems. This permits a unit that is more compact and easier to feed. The unit also produces lower emissions and uses less sorbent materials than the fluidized bed systems. No off-gas scrubber is necessary in the circulating bed combustor and heat can be recovered as an added benefit.

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Status/Availability: Ready for field-scale testing.

Manufacturer: G. A. Technologies

Users: _____

EPA Contact: Donald Oberacker, (513) 569-7341

Technology: Distillation

Brief Description: Separates miscible organic liquids for solvent reclamation and waste volume reduction. The resulting residuals are still bottoms and "slop" or intermediate distillate cuts. Two major types of distillation processes are batch distillation and continuous fractional distillation.

Applicability/Limitation: Used to treat liquid organic wastes, primarily spent solvents, either halogenated such as, spent 1,1,1-trichloroethane degreasing solvent or non-halogenated compound such as methyl ethyl ketone solvent mixture from paint line clean-out. Liquids to be separated must have different volatilities. The limitations are heat-sensitive suspended solids and azeotropes. Batch distillation in a heated still pot with condensation of the overhead vapors is easily controlled and flexible, but cannot achieve the high product purity of continuous fractional distillation. Small packaged batch stills treating one drum per day or less are becoming popular for on-site recovery of solvents. Continuous fractional distillation is accomplished in tray columns or packed towers ranging up to 40 feet in diameter and 200 feet high. Each is equipped with a reboiler, a condenser, and an accumulator. The capacity of a unit is a function of the waste being processed, purity requirements, reflux ratio and heat input.

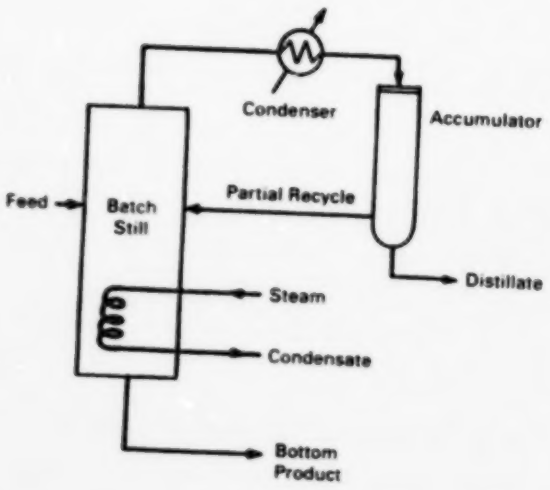
Status/Availability: _____

Manufacturer: Exceltech, Inc., John Sedwick, (415) 659-0404
Kipin Industries, Peter Kipin, (412) 495-6200
Mobile Solvent Reclaimers, Inc., Larry Lambing, (816) 271-4392

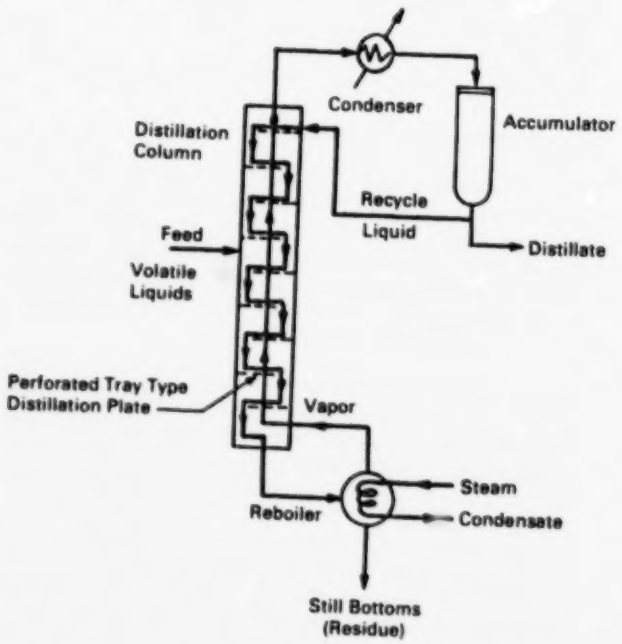
Users: _____

EPA Contact: Ron Turner, (513) 569-7775

Batch distillation.



Continuous fractional distillation.



Technology: Electric Reactors

Brief Description: Use an electrically heated fluid wall reactor to pyrolyze waste contaminants from particles such as soils. Emissions and residuals include mostly N_2, H_2O and Cl_2 and/or HCl trapped in the scrubber ash components in the residue. The advantages are that it is transportable, has a high treatment efficiency, and emissions are low.

Applicability/Limitation: Used to treat organics, inorganics in solid, liquid or gas (solid or liquid may require pretreatment) and for PCB or dioxin contaminated soils. It is limited to treating solids less than -35 U.S. mesh and liquids atomized to <1500 micron droplets.

Status/Availability: Commercial units are under construction, none in use.

Manufacturer: Thagard Research Corporation, Costa Mesa, California
J. M. Huber Construction, Jim Boyd (806) 274-5040

Users: Two units in Borger, Texas.

EPA Contact: Harry Freeman, (513) 569-7529

Technology: Electrolytic Oxidation

Brief Description: In this process cathodes and anodes are immmersed in a tank containing a waste to be oxidized, and a direct electrical current is imposed on the system. The process is particularly applicable to cyanide bearing waste. The products of decomposition for cyanide waste are ammonia, urea, and carbon dioxide. During the decomposition, metals present are plated out on a cathode.

Applicability/Limitation: Used to treat high concentrations (up to 10 percent) of cyanide and to separate metals and allow their potential recovery. Limitations include physical form (such as sludge or solids), non-selective competition with other species and long process time at up to 200°F.

Status/Availability: Commercially available.

Manufacturer: Stauffer Chemical Company

Users: _____

EPA Contact: S. Garry Howell, (513) 569-7756

Technology: Evaporation

Brief Description: Evaporation is the physical separation of a liquid from a dissolved or suspended solid by the application of energy to volatilize the liquid. In hazardous waste treatment, evaporation may be used to concentrate a hazardous material thus reducing the volume of waste requiring subsequent treatment or disposal.

Applicability/Limitation: Evaporation can be applied to any mixture of liquids and non-volatile solids provided the liquid is volatile enough to evaporate under reasonable heating or vacuum conditions. (Both the liquid and the solid should be stable under those conditions.) If the liquid is water, evaporation can be carried out in a large pond with solar providing the energy. Evaporation of aqueous wastes can also be done in closed process vessels with energy provided by steam and the resulting water vapor condensed for possible reuse. Energy requirements are usually minimized by such techniques as vapor recompression or multiple-effect evaporators.

Evaporation is applied to solvent wastes comtaminated with nonvolatile impurities such as oil, grease, paint solids, or polymeric resins. Mechanically agitated or wiped thin film evaporators are used. Solvent is evaporated and recovered for reuse. The residue is the bottom stream, typically containing 30 to 50 percent solids.

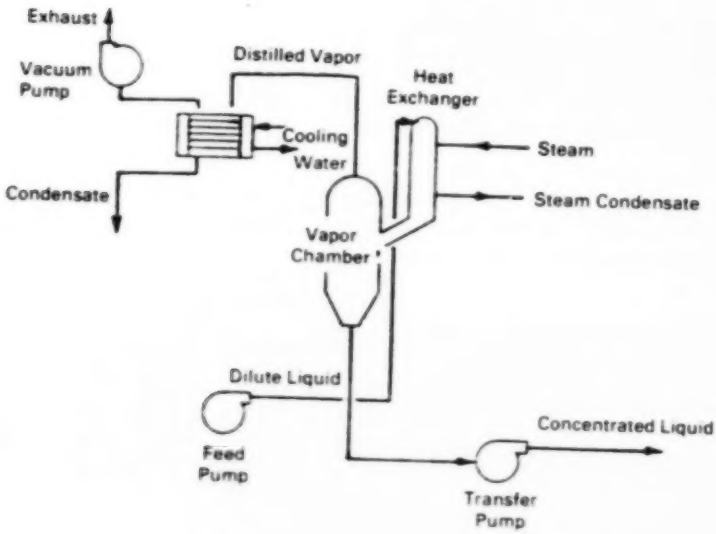
Status/Availability: Commercially available.

Manufacturer: Resources Convervation Company, (Mobile Brine Concentration Systems), Bellevue, Washington

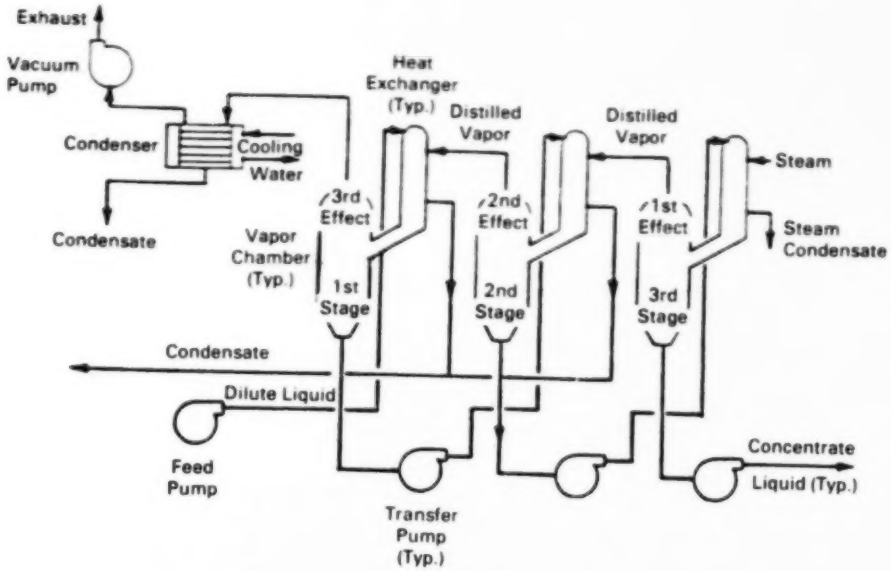
Users: _____

EPA Contact: Ron Turner, (513) 569-7775

Schematic of single and multiple effect evaporators.



Typical Single Effect Evaporator—Falling Film Type



Typical Multi-Effect (Triple Effect) Evaporator—Falling Film Type

Technology: Extraction/Soil Flushing or Washing

Brief Description: Removes toxic/hazardous organics and inorganics from soil or sludge by extracting contaminants by partitioning. The site is flooded with the appropriate flushing solution and the elutriate is collected. The resulting waste-containing elutriate is treated.

Applicability/Limitation: Used to remove both organics and inorganics if they are sufficiently soluble in a solvent. Surfactants can be used for hydrophobic organics.

Status/Availability: Commercially available.
EPA Mobile In-Situ/Containment Treatment Unit

Manufacturer: Critical Fluid Systems, Peter Dunlap, (617) 492-1631
IT Corporation, Dave Sikes, (415) 228-5100

Users: Volk Air National Guard Base, Wisconsin (found not viable)
Lee's Farm, Wisconsin, (312) 535-2318
Celtor Chemical Works
Hoopa Indian Reservation, Nick Morgan, (916) 243-5831

EPA Contact: Ron Turner, (513) 569-7775
Richard P. Traver, (.)2) 321-6677

Technology: Filtration

Brief Description: Granular media filtration usually uses gravity to remove solids from a fluid by passage of the fluid through a bed of granular material. Several mechanisms are involved in the removal of suspended solids by granular media filtration. They include straining, physical adsorption and coagulation-flocculation. In vacuum and high-pressure filtration pressure (either negative or positive) is used to move water through the filter media and leaving the solids behind. These filters may be precoated with a filter aid such as a ground cellulose, diatomaceous earth, etc.

Applicability/Limitation: Filtration is used for the dewatering of sludges and slurries as a pretreatment for other processes. Filtration does *not* reduce the toxicity of the waste. Although sometimes powdered activated carbon may be used as a combination adsorbent and filter aid, it merely reduces the volume of waste to be treated. Filtration should not be used with sticky or gelatinous sludges, this is due to likelihood of filter media plugging. Granular media should be preceded by gravity separation if suspended solids are greater than 100 mg/l. Design criteria—In granular bed filtration rates range from 2 gpm/sf for shallow beds of fine sand to over 15 gpm/sf for deep bed filters using coarse sand or multiple media beds. Vessels are from 2½ to 20 feet in diameter, with media depth of 1½ to over 15 feet.

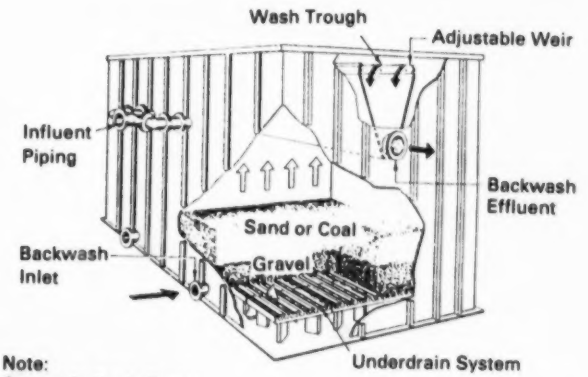
Status/Availability: Commercially available.

Manufacturer: Granular Media Filters
Calgon Carbon Corporation, Dave Jordan, (201) 526-4646
Carbon Air Services, Inc., (612) 935-1844
Chemical Waste Management, John Fink, (714) 940-7971
Dorr-Oliver
Krauss-Maffei, (316) 945-5251
Komline Sanderson, (201) 234-1000
Bird Machine Co., (617) 668-0400
DR Sperry, Inc., (312) 892-4361

Users: Widely used.

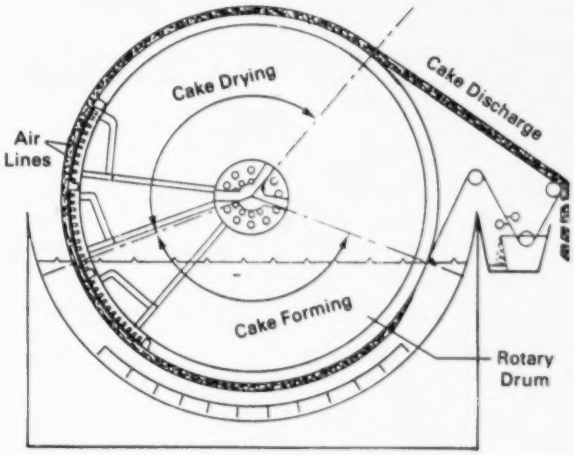
EPA Contact: S. Garry Howell, (513) 569-7756

Packaged granular media gravity filter.

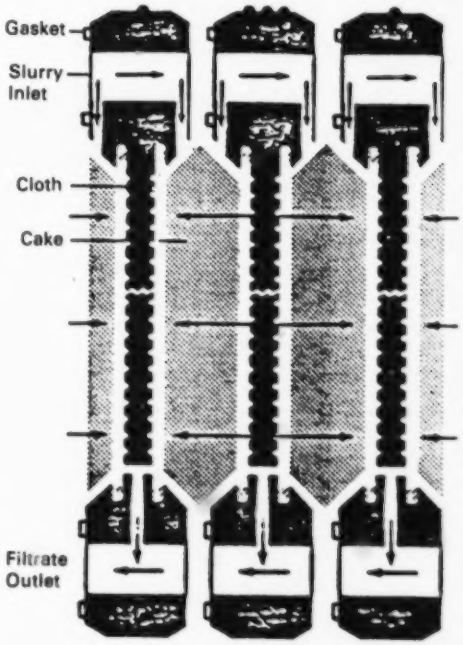


Note:
Arrows Indicate Route of Backwash

Vacuum filter.



Filter press unit.



Technology: Fluidized Bed Incinerators

Brief Description: Utilize a very turbulent bed of inert granular material (usually sand) to improve the transfer of heat to the waste streams to be incinerated. Residues and emissions include acid gases trapped in the bed, low particulates, low nitrogen oxides and ash components (for low-ash wastes). Advantages of this technology include low temperature with no ash agglomeration, low gas emissions, low particulate emissions and a long residence time. Operating temperatures range from 1300 to 2100°F, gas residence times are usually several seconds, and excess air rates are normally 40 percent. Heat release rates range from 100,000 to 200,000 Btu/hr/ft^3.

Applicability/Limitation: Not presently used for hazardous waste commercially. Refractory wastes may not be destroyed.

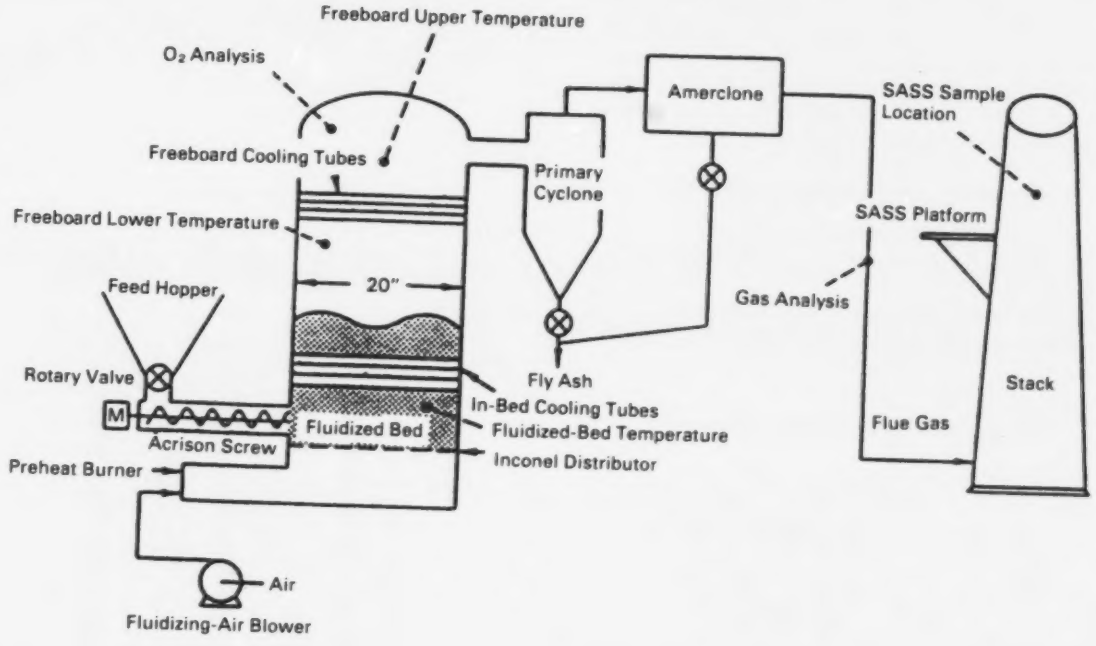
Status/Availability: Commercially available.

Manufacturer: Battelle, Jack Conner, Columbus, Ohio
GA Technologies, William Rickman, (619) 455-3860
Dorr-Oliver
Waste-Tech Services, Inc., (208) 522-0850
(303) 987-1790 (mobile)

Users: _____

EPA Contact: Harry M. Freeman, (513) 569-7529

Energy Resources Company's pilot-plant FBC facility.



Technology: Fly Ash or Lime-Based Pozzolan Stabilization/ Solidification

Brief Description: This technology involves the addition of large amounts of a siliceous material combined with a setting agent such as lime, cement or gypsum resulting in dewatering, stabilized, solidified product. Also can use thermoplastic (asphalt, polyethylene).

Applicability/Limitation: Used for sludges and contaminated soils including metals, waste oils and solvents. Materials such as borates, sulfates and carbohydrates interfere with the process. Long-term stability and resistance to leaching unknown in some cases.

Status/Availability: Commercially available.

Manufacturer: Different silicate processes available.

Users: _____

EPA Contact: Carlton Wiles, (513) 569-7795

Technology: Fuel Blending

Brief Description: Method to reuse waste organics as fuel substitutes. The objective is the controlled blending of segregated wastes of known characteristics into a fuel product whose chemical and physical characteristics meet the fuel specifications of the fuel user.

Applicability/Limitation: Used to combine waste oils, solvents and organic sludges to produce a material with a fuel value usually greater than 10,000 Btu/lb. Limitations include chlorine and water content, the waste viscosity and the need for low solids. In addition, the presence of certain hazardous constituents (such as PCBs) and the corrosivity of the waste can be limiting criteria for certain wastes.

Status/Availability: In use for lime and cement manufacturing, process heating and blast furnace operation where permitted.

Manufacturer: _____

Users: Solid Tek Systems, Inc., (404) 361-6181

EPA Contact: Ron Turner, (513) 569-7775

Technology: Granular Media Filtration

Brief Description: Granular media filtration uses gravity to remove solids from a fluid by passage of the fluid through a bed of granular material. Several mechanisms are involved in the removal of suspended solids by granular media filtration. They include straining, physical adsorption and coagulation-flocculation. A granular media filter therefore can remove particles much smaller than the void size of the filter media. Filters may be open top with gravity feed, or enclosed in a pressurized vessel. The range of configurations available include many proprietary designs related primarily to improvements in the backwashing operation.

Applicability/Limitation: Granular media filtration is typically used after gravity separation processes for additional removal of suspended solids and oils prior to the other treatment processes and as a polishing step for treated wastes to reduce suspended solids and associated contaminants to low levels. Pretreatment by filtration is appropriate for membrane separation processes, ion exchange, and carbon adsorption in order to prevent plugging or overloading of these processes. Filtration of settled waste is often required to remove undissolved heavy metals which are present as suspended solids to ensure meeting effluent quality requirements. Granular media filtration should be preceded by pretreatment processes if the suspended solid concentration exceeds about 100 mg/l. Otherwise, premature plugging will occur.

Status/Availability: Commercially available.

Manufacturer: Calgon Carbon Corporation, Dave Jordan, (201) 526-4646
Carbon Air Services, Inc., (612) 935-1844
Chemical Waste Management, John Fink, (714) 940-7971

Users: _____

EPA Contact: S. Garry Howell, (513) 569-7756

Technology: Hydrolysis

Brief Description: Enhances cleavage rates of organic molecules (breakdown to simpler, less-toxic compounds) by acceleration of acid or base-catalyzed hydrolysis rates through adjustment of soil/groundwater/sludge pH.

Applicability/Limitation: Applicable in-situ treatment, e.g., pesticide spills. Acid hydrolysis not recommended for in-situ treatment because of potential mobilization of heavy metals. Base-catalyzed hydrolysis attractive because of pH adjustment by lime, alkaline fly ash, or sodium carbonate.

Status/Availability: Used at several sites.

Manufacturer: Not applicable.

Users:

EPA Contact: Donald Sanning, (513) 569-7875

Technology: Industrial Boilers

Brief Description: Hazardous waste is used as supplementary fuel to coal, oil or natural gas in fire tube and water tube industrial boilers. Hazardous waste fuel (HWF) (generally limited to liquid wastes) can be blended with primary fuel and fired into a boiler with primary fuel or it can be fired alone through other burners. The heat release rate of boilers that have been tested with HWF ranges from 100 to 800 x 10^3 Btu/ft^3/hr.

Applicability/Limitation: Chlorine and sulfur must be limited to HWF to minimize corrosion of boiler materials of construction and to avoid increases in HCl and sulfur oxide air emissions. Solids hazardous wastes such as contaminated soils are not applicable for use as HWF in boilers. Particularly useful for the disposal of hazardous wastes generated on site.

Status/Availability: Only a small fraction of the nations 23,000 fossil fueled boilers are in use burning HWF.

Manufacturer: Various manufacturers. May be package units or field constructed.

Users: Hazardous waste generators may use on-site boilers to destroy combustible wastes.

EPA Contact: Robert E. Mournighan, (513) 569-7408

Technology: Industrial Kilns (Cement, Lime, Aggregate, Clay)

Brief Description: Rotary kilns constructed of steel casings lined with refractory brick. Blended feed material is fed into the upper (higher) end of the kiln and fuel (coal, gas, oil, or hazardous waste) is fired at the lower end. Kiln temperatures are about 3000°F for lime kilns, and less than 2000°F for aggregate and clay drying kilns. Hazardous waste fuel usually fired into kiln with separate burner than primary fuel. Waste blending may be necessary to obtain desired fuel characteristics.

Applicability/Limitation: Generally limited to liquid waste. Chlorine and sulfur content of waste fuel must be controlled to prevent kiln operating and product quality problems. Contaminated soils are not good candidates for treatment in industrial kilns.

Status/Availability: 280 cement and lime kilns but use of hazardous waste fuel not widespread. At least 11 cement kilns now burn HWF as supplemental fuel.

Manufacturer: Various manufacturers. Kilns are field constructed.

Users: Off-site HWF generators.

EPA Contact: Robert Mournighan, (513) 569-7408

Technology: Infrared Incineration Systems

Brief Description: The primary chamber consists of a rectangular cross section "box" of carbon steel lined with layers of lightweight ceramic fiber blanket. Infrared energy is provided by silicon carbide resistance heating elements. The material to be processed is conveyed through the furnace on a woven wire belt through the furnace. When the material reaches the discharge end of the furnace, it drops off of the belt into a hopper. The residuals are the gaseous products of waste combustion, low particulates and solid residuals. The advantages include a quiescent combustion zone for low particulate emissions, reduced gaseous emissions since no fossil fuel is used, up to 50 percent turndown, the system allows a high degree of control and long residence times are achievable.

Applicability/Limitation: Used to treat solids, sludges and contaminated soils. The process is used primarily for solids or sludges, but liquid or gaseous injection systems are available.

Status/Availability: Operational units at several locations, mobile units under construction, pilot-test unit available.

Manufacturer: Shirco Infrared Systems, Jim Welsh, (214) 630-7511

EPA Contact: Harry M. Freeman, (513) 569-7529

Technology: In-Situ Adsorption (Permeable Treatment Beds)

Brief Description: A trench, excavated down to a confining layer, is filled with adsorbent or chemical treatment material, such as activated carbon, diatomaceous earth, fly ash, zeolites, lime or sodium carbonate (to raise pH). Contaminated groundwater is treated as it percolates through the beds.

Applicability/Limitation: Beds must be sufficiently permeable to allow passage of ground water. Bed pores may clog up, beds require renovation or replacement.

Status/Availability: Not used in full scale yet.

Manufacturer: _____

Users: _____

EPA Contact: Donald Sanning, (513) 569-7875

Technology: In-Situ Chemical Immobilization

Brief Description: Heavy metals are stabilized in the ground as insoluble precipitates (sulfides, phosphates, hydroxides, carbonates) or oxidized forms (e.g., ferric hydroxide with Mn coprecipitate). Alternatively some reduced forms are more stable (Cr[III], Se[IV]). Certain organic monomers can be stabilized as polymers.

Applicability/Limitation: Applies mostly to heavy metals. The in-situ conditions must be maintained to avoid reversion of the stabilized form to a more mobile form (e.g., sulfides can be oxidized to sulfates, remobilizing the heavy metals).

Status/Availability: EPA Mobile In-Situ/Containment Treatment Unit.

Manufacturer: Not applicable.

Users: _____

EPA Contact: Donald Sanning, (513) 569-7875
Richard Traver, (201) 321-6677

Technology: In-Situ Thermal Destruction

Brief Description: Radio-frequency (RF) electrodes placed along the ground surface heat the shallow subsurface and generate superheated steam from ground water. Organics are destroyed or mobilized by vaporization, thermal decomposition, or distillation.

Applicability/Limitation: High operating costs (electric power). Probably most applicable to volatile, low boiling point, or easily decomposed organic compounds.

Status/Availability: Not used on full scale yet.

Manufacturer: Illinois Institute of Technology has done research.

Users: _____

EPA Contact: Donald Sanning, (513) 569-7875

Technology: Ion Exchange

Brief Description: Removes toxic metal ions from solution to recover concentrated metal solutions for recycling by exchanging one ion, electrostatically attached to a solid resin material for a dissolved toxic ion. The resulting residuals include spent resins and spent regenerants such as acid, caustic or brine.

Applicability/Limitation: This technology is used to treat metal wastes including cations (Ni^{2+}, Cd^{2+}, Hg^{2+}) and anions (CrO_4^{2-}, SeO_4^{2-}, $HAsO_4^{2-}$). Limitations are selectively/competition, pH, and suspended solids. The oxidizing agent concentration should be greater than 50 meq/l for practical operation. Highly concentrated waste streams (>2500 mg/l contaminants) or high solid concentrations (>50 mg/l) should be avoided.

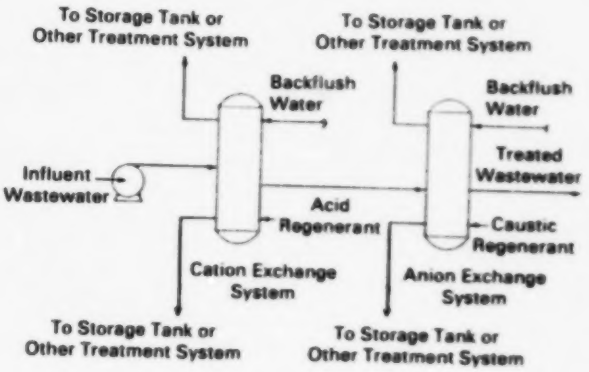
Status/Availability: Commercially available.

Manufacturer: See buyer's guides from trade journals.

Users: Used on full commercial scale for water treatment/conditioners.

EPA Contact: S. Garry Howell, (513) 569-7756.

Schematic of ion exchange.



Technology: Liquid Injection Incineration

Brief Description: Waste material is introduced to the combustion chamber in various droplet sizes to mix with air and fuel, as needed. Following combustion, the resulting gases are cooled and treated to remove particulates and to neutralize acid gases. Pretreatment such as blending, may be required for wastes to provide efficient mixing with the oxygen source. Operating temperatures range from 1200° to 1300°F and the gas residence time ranges from 0.1 to 2.0 seconds. Typical heat output ranges from 1 to 100 MMBtu/hr.

Applicability/Limitation: Can be applied to all pumpable organic wastes including wastes with high moisture content. Care must be taken in matching waste to specific nozzle designs. Wastes with high moisture content, high inorganic content or which contain heavy metals are restricted.

Status/Availability: Ensco has a mobile unit available, used with rotary kilns. EPA Mobile Unit/Incineration System is available.

Manufacturer: Several, see buyer's guide from trade journals.

Users: EPA Region VII, James Denny Farm, Missouri (dioxin destruction).

EPA Contact. Donald Oberacker, (513) 569-7431
Frank J. Freestone, (201) 321-6632

Technology: Macroencapsulation/ Overpacking

Brief Description: Encapsulates large particles in an environmentally secure barrier using lime or cement pozzolan, thermoplastic or organic polymer. A matrix is formed from reactive components, but the waste not uniformly dispersed. The product containing the waste is in nodule form. Product placement technique is very important.

Applicability/Limitation: Some processes are applicable to both organics and inorganics. Advantages—The waste nodules are isolated, improved handling, low permeability, minimum treatment, good beaming strength. Disadvantages—Presence of free liquid and the resultant product can be leachable.

Status/Availability: _____

Manufacturer: _____

Users: _____

EPA Contact: Robert Landreth, (513) 569-7839

Technology: Molten Glass

Brief Description: Uses a pool of molten glass as the heat transfer mechanism to destroy organics and to capture ash and inorganics. The emissions include acid gas and particulates and all residue is contained in the glass. The advantages include significant volume reduction, most wastes are treatable, the residual is stabilized glass. Process is based on existing glassmaking technology.

Applicability/Limitation: Used to treat any solid or liquid such as plastics, asphalt, PCB or pesticides. Sodium sulfates greater than 1 percent of the final glass may pose a problem. It is inappropriate for soils or high ash waste and it requires additional treatment for off-gas.

Status/Availability: Commercially available for uses other than hazardous waste incinerators.

Manufacturer: Penberthy Electromelt International, Inc., (206) 762-4244
Battelle—Northwest, (509) 375-2927

Users: _____

EPA Contact: Harry M. Freeman, (513) 569-7529

Technology: Molten Salt

Brief Description: Waste material is injected beneath a bed of molten sodium carbonate for incineration. Inorganics trapped in the salt include phosphorus, sulfur, arsenic and halogens. The salt acts as a gas scrubber so there are low concentrations or no acid gas emissions, the scrubber controls particulates and the salt/ash mixture makes up the solid residue. Reaction temperatures in the bed range from 1500 to 2000°F and residence times are typically 0.75 seconds.

Applicability/Limitation: Used to treat low ash, low water content solid or liquid wastes. Limitations are that low ash, and low water content are required and molten salt can be corrosive. The neutralization of acid gases results in the formation of other salts that can change the fluidity of the bed and hence, require frequent replacement of bed material.

Status/Availability: Pilot-scale units available.

Manufacturer: Rockwell International, (213) 700-8200

Users:

EPA Contact: Harry M. Freeman, (513) 569-7529

Technology: Multiple Hearth Incinerator

Brief Description: Sludge or granulated solid combustible waste feeds through the furnace roof where a rotating air-cooled central shaft with air-cooled rabble arms and teeth plows the waste across the top hearth to dropholes where it falls to the next successive hearth until the ash is discharged at the bottom.

Applicability/Limitation: Disposes of sludges, tars, solids, gases and liquid combustible wastes (through nozzles). Not recommended for hazardous wastes.

Status/Availability: Commercially available.

Manufacturer: See buyer's guide for trade journals.

Users: Most widely used sewage sludge incineration method.

EPA Contact: Donald Oberacker, (513) 569-7431

Technology: Neutralization

Brief Description: Renders acid or caustic wastes non-corrosive by pH adjustment. The resulting residuals include insoluble salts, metal hydroxide sludge, and neutral effluent containing dissolved salts. The final desired pH is usually between 6.0 and 9.0.

Applicability/Limitation: Used to treat corrosive wastes, both acids and bases. Limitations may include concentration, the physical form such as sludges or solids and the need for corrosion-resistant equipment.

Status/Availability: Commercially available.

Manufacturer: Newpark Waste Treatment Systems, Inc., James Hobby, (419) 586-6683
Solid Tek Systems, Inc., (404) 361-6181
Ecolochem, Inc., Richard Smallwood, (800) 446-8004
CECOS, Ernest C. Neal, (716) 873-4200

Users: Widespread.

EPA Contact: S. Garry Howell, (513) 569-7756

Technology: Oxidation by Hydrogen Peroxide (H_2O_2)

Brief Description: Addition of H_2O_2 to oxidize organic compounds. H_2O_2 can be used as a source of oxygen for biodegradation.

Applicability/Limitation: Non-specific reaction. May be exothermic/explosive or require addition of heat and/or catalysts. Probably not applicable for in-situ treatment; may be used for surface treatment of contaminated ground water/sludges.

Status/Availability: Common industrial unit process.

Manufacturer: Various, FMC sells hydrogen peroxide and nutrient for biodegradation specifically for petroleum treatment.

Users: _____

EPA Contact: Ronald Lewis, (513) 569-7856

Technology: Oxidation by Hypochlorites

Brief Description: Addition of sodium or calcium hypochlorite (bleaching agents) to oxidize organic wastes.

Applicability/Limitation: May produce toxic chlorinated organic by-products. Must be done under controlled (not in-situ) conditions, i.e., batch reactors. Non-specific reaction.

Status/Availability: Used in industrial processes.

Manufacturer: See buyer's guide in trade journals.

Users: _____

EPA Contact: Donald Sanning, (513) 569-7875

Technology: Ozonation

Brief Description: Ozonation is a chemical oxidation process appropriate for aqueous streams which contain less than 1.0 percent oxidizable compounds.

Applicability/Limitation: Ozone can be used to pretreat wastes to breakdown refractory organics or as a polishing step after biological or other treatment processes to oxidize untreated organics. Ozone is currently used for treatment of hazardous wastes to destroy cyanide and phenolic compounds. The rapid oxidation of cyanides with ozone offers advantages over the slower alkaline chlorination method. Limitations include the physical form (i.e., sludges and soilds) and nonselective competition with other species.

Status/Availability: Commercially available.

Manufacturer: See buyer's guides or trade journal.

Users: Widespread.

EPA Contact: S. Garry Howell, (513) 569-7756
Donald Sanning, (513) 569-7875

Technology: Plasma Systems

Brief Description: This technology uses a plasma arc device to create extremely high temperatures (temperatures approach 10,000°C) for waste destruction in highly toxic liquids. Gaseous emissions (mostly H_2, CO), acid gases in the scrubber and ash components in scrubber water are the residuals. The system's advantages are that it can destroy refractory compounds, the equipment can be made portable and typically the process has a very short on/off cycle.

Applicability/Limitation: Used to treat liquid wastes containing organics, pesticides, PCBs, dioxins or halogenated organics. The process is limited to liquids and continuous operation has not been demonstrated.

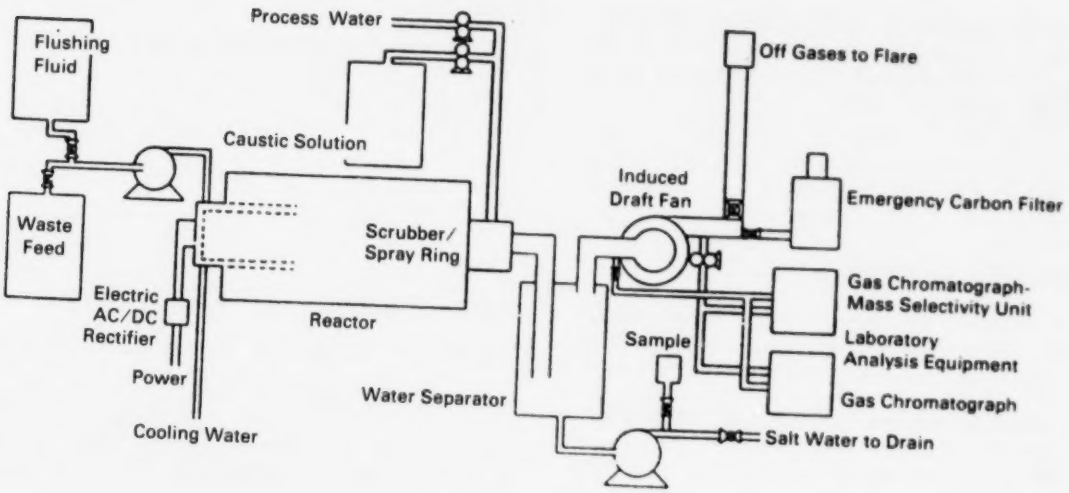
Status/Availability: Pilot-plant stage with demonstration in progress, mobile pilot plant available.

Manufacturer: Pyrolysis Systems, Inc., Ed Fox, (416) 735-2401
Applied Energetics, Inc., John Dicks, (615) 455-0631
Westinghouse

Users: _____

EPA Contact: Harry M. Freeman, (513) 569-7529

Process schematic of the psi plasma pyrolysis unit.



Technology: Polymerization

Brief Description: Polymerization uses catalysts to convert a monomer or a low-order polymer of a particular compound to a larger chemical multiple of itself which has different properties for in-place stabilization.

Applicability/Limitation: This technology treats organics including aromatics, aliphatics and oxygenated monomers such as styrene, vinyl chloride, isoprene acrylonitrile, etc. Limited application to spills of these compounds.

Status/Availability: Has been used at spills.

Manufacturer: Not applicable.

Users: _____

EPA Contact: Carlton Wiles, (513) 569-7795

Technology: Portland Cement Pozzolan Stabilization/Solidification

Brief Description: Mixes the waste with portland cement to incorporate the waste into the cement matrix. This improves handling and is inexpensive (plentiful raw materials).

Applicability/Limitation: Effective for metal cations, latex and solid plastic wastes. Large amounts of dissolved sulfate salts, or metallic anions such as arsenate and borates will hamper solidification. Organic matter, lignite, silt or clay will increase setting time.

Status/Availability: Commercially available.

Manufacturer: Aerojet Energy Conversion Company, Sacramento, California
ATCOR, Inc., Peekskill, New York
Chem-Nuclear Systems, Inc., Bellevue, Massachusetts
Delaware Custom Materials, Cleveland, Ohio
Energy, Inc., Idaho Falls, Idaho
General Electric Company, San Jose, California
Hittman Nuclear and Development Company, Columbia, Maryland
Stock Equipment Company, Cleveland, Ohio
Todd Research and Technical Division, Galveston, Texas
United Nuclear Industries, Richland, Washington
Westinghouse Electric Company, Pittsburgh, Pennsylvania

Users: _____

EPA Contact: Robert Landreth, (513) 569-7836

Technology: Pyrolysis Processes

Brief Description: Pyrolysis consists of heating material in the absence of air in order to thermally degrade to a volatile gaseous portion and residual solid comprised of fixed carbon and ash. There are two main ways to heat the material. One is by direct heating where the material is heated by direct contact with hot combustion products. The result of direct heating is an off-gas that is a combination of volatiles from the waste and burner flue products. Another method is indirect heating. This method keeps the burner flue products from mixing with the volatiles. Indirect heating is the necessary mode of heating if resource recovery is to be attempted, but it is also more complex and more expensive than direct heating. Indirect heating will probably prove economical only in very large units. Because of the drawbacks of indirect heating Midland-Ross is concentrating on smaller units that can convert the waste to a preheated gaseous fuel and burn the fuel near the pyrolyzer. In this way direct heating imposes almost no penalty on overall fuel efficiency.

The pyrolysis equipment is designed to convert waste that is not suited for boiler fuel, into a gaseous fuel. The main objective of this system is to convert waste material from a disposal problem to a gaseous fuel source.

Applicability/Limitation: This technology is used to treat viscous liquids, sludges, solids, high ash materials, salts and metals and halogenated wastes. The limitations are that it requires a homogeneous waste input and metals and salts in the residue can be leachable.

Status/Availability: Commercially available batch and continuous.

Manufacturer: Midland-Ross Corporation, (419) 547-6444

Users: _____

EPA Contact: Harry M. Freeman, (513) 569-7529

Technology: Rotary Kiln Incineration

Brief Description: Wastes and auxiliary fuel are introduced to the high end of the kiln which is slightly inclined to horizontal. Wastes are oxidized, or combusted as they move through the kiln due to its rotation. Exhaust gases from the kiln pass to a secondary chamber, or afterburner for further oxidation. Ash residues are discharged and collected from the low end of the kiln. Exhaust gases may require acid gas and particulate removal, and the ashes may require solidification before landfilling.

Applicability/Limitation: Most types of solid, liquid and gaseous organic wastes can be treated with this technology. Wastes with high inorganic salt content and heavy metals as well as explosive wastes require special evaluation.

Status/Availability: Commercially available and in wide use.

Manufacturer: S. D. Myers, Inc., Joe Isle, (415) 794-6301
American Industrial Waste of ENCSO, Inc., (Mobile), (615) 383-1691
Exceltech, Inc., (415) 659-0404
International Waste Energy System, Dwight Brown, (314) 389-7275
Winston Technology, Inc., (Mobile), (914) 273-6533
Industronics, Inc., (203) 289-1551
Volund USA, (312) 655-1490
Thermal
TR Systems
C & H Combustion
CE Raymond
Von Roll

Users: EPA-ORD, Denny Farm Site near McDonnell, Missouri.

EPA Contact: James Yezzi, (201) 321-6677

Technology: Soil Flushing/Soil Washing

Brief Description: Soil flushing is in-situ extraction of inorganic or organic compounds from soils by passing extractant solutions through the soils. These solutions may include water, surfactants, acids or bases (for inorganics), chelating agents, oxidizing and reducing agents. Soil washing consists of similar treatment, but the soil is excavated and treated at the surface in a soil washer.

Applicability/Limitation: Soil flushing/washing fluids must have good extraction coefficients, low volatility and toxicity, be safe and easy to handle, and most important, be recoverable/recyclable. Most promising for extraction of heavy metals, problems likely in dry or organic-rich soils. Care must be taken that the soil pores are not clogged. This can happen with certain surfactants tested for in-situ extraction.

Status/Availability: Limited full-scale testing.

Manufacturer: USEPA, Edison, New Jersey, has mobile soil washer, other systems under development.

Users: Technology has been developed by oil industry (tertiary recovery) and mining (metal leaching).

EPA Contact: Richard Traver, (201) 321-6677

Technology: Sorption

Brief Description: Contaminants are bound up in pozzolan-type matrices by physical sorption or chemisorption yielding a stabilized material which is easier to handle. Liquid immobilization depends on added ingredients. This process results in high concentrations of contaminants at the surface of the material and contaminants may leach. The treated material is permeable.

Applicability/Limitation: For organics and inorganics. Advantages to this technology include plentiful raw materials, mixing technology known, improved handling, inexpensive additives, minimum pretreatment, bearing strength adequate for landfill. Disadvantages—large volume of additives, poor leachate control, placement sensitive, limited bearing strength, free water may be released under high pressure and there is temperature sensitivity.

Status/Availability: _____

Manufacturer: _____

Users: _____

EPA Contact: Robert Landreth, (513) 569-7836

Technology: Steam Stripping

Brief Description: Uses steam to remove organics from aqueous wastes. Steam stripping is essentially a continuous fractional distillation process carried out in a packed or tray tower. Clean steam rather than reboiled bottoms provides direct heat to the tower. The resulting residuals are contaminated steam condensate, recovered solvent, and "stripped" effluent.

Applicability/Limitation: Used to treat aqueous wastes contaminated with chlorinated hydrocarbons, aromatics such as xylenes, ketones such as acetone or MEK, alcohols such as methanol and high boiling point chlorinated aromatics such as penta-chlorophenol. Steam stripping will treat less volatile and more soluble wastes than air stripping and can handle a wide concentration range from less than 100 ppm to 10 percent organics.

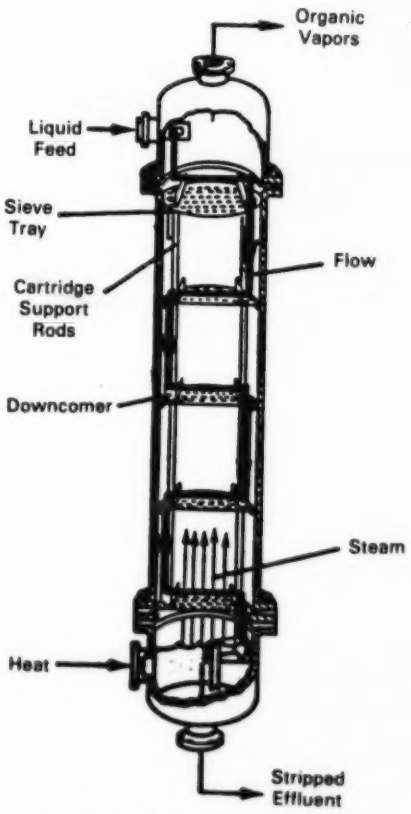
Status/Availability: USEPA has transportable unit.

Manufacturer: _____

Users: _____

EPA Contact: Ron Turner, (513) 569-7775

Steam stripping column—perforated tray type.



Source: Pfaudler, Rochester, New York

Technology: Sulfur Regeneration Units

Brief Description: Proprietary sulfuric acid regeneration unit is used to combust high sulfur refinery waste. Sulfur is recovered from the combustion gases using a double contact-double absorption sulfuric acid plant. The furnace operates above 1600°F, and has a long residence time (greater than 1 second).

Applicability/Limitation: Can destroy hazardous waste with high sulfur content. Particularly appicable to high sulfur, high Btu refinery wastes.

Status/Availability: Limited.

Manufacturer: Stauffer Chemical proprietary process.

Users: Destroys on-site generated wastes.

EPA Contact: Harry Freeman, (513) 569-7529

Technology: Supercritical Extraction

Brief Description: At a certain combination of temperature and pressure, fluids reach their critical point beyond which their solvent properties are greatly altered. These properties make extraction more rapid and efficient than processes using distillation and conventional solvent extraction methods. This technology has not been applied to PCBs. No cost or time estimates are available. Presently, the EPA has contracted Critical Fluid Systems, Inc., to investigate the use of supercritical carbon dioxide to extract hazardous organics from aqueous streams.

Applicability/Limitation: This technology is used to extract hazardous waste from the soil. It is limited at this time because it is new and it appears that the capital cost is high.

Status/Availability: Laboratory tests only.

Manufacturer: _____

Users: _____

EPA Contact: Charles Rogers, (513) 569-7757

Technology: Supercritical Water Oxidation

Brief Description: The supercritical water oxidation process is basically a high temperature, high pressure wet air oxidation. The unique properties of water above 500°C or 705°F (supercritical region) cause it to act as an excellent non-polar solvent for nearly all organic materials. Aqueous solutions or slurries (organic content >5 percent) are mixed with high-pressure oxygen (3200 to 3600 psi or >218 atms) to chemically oxidize wastes in less than one minute with >99.99 percent efficiency. The process is an emerging technology which may be less expensive than high-temperature incineration for destruction of organically contaminated aqueous wastes.

Two processing approaches have been evaluated: an above-ground pressure vessel reactor (MODAR) and the use of an 8,000 to 10,000-ft well reactor (Vertox). The SCW process is best suited for large volume (200 to 1000 gpm) dilute (1.0 to 10,000 mg/l COD) aqueous wastes that are of a volatile nature and that contain sufficient Btu's to sustain the process. In many applications, high Btu non-hazardous wastes can be mixed with low Btu hazardous wastes to provide the heat energy needed to make the process self sustaining. Emissions/residues include gaseous effluent (nitrogen and carbon dioxide), precipitation of inorganic salts and the liquid containing only soluble inorganic acids and salts. The advantages are rapid oxidation rates, complete oxidation of organics, efficient removal of inorganics and no off-gas processing is required.

Applicability/Limitation: Used to treat aqueous organic solution/slurry and mixed organic/inorganic waste. Sophisticated equipment and operations and long-term continuous operation have not been demonstrated, thereby limiting its use.

Status/Availability: Demonstration completed in 1985, commercial unit available in 1987.

Manufacturer: Vertox Corporation, Dallas, Texas
MODAR, Inc., Natick, Texas (pilot scale)

Users: _____

EPA Contact: Harry M. Freeman, (513) 569-7529
Charles Rogers, (513) 569-7757

Technology: Ultraviolet Photolysis

Brief Description: Ultraviolet photolysis (UV) is a process that destroys or detoxifies hazardous chemicals in aqueous solutions utilizing UV irradiation. Natural photolysis of dioxins has been observed on soil surfaces although the degree of reaction is limited by the depth of penetration of the UV. Ultraviolet light has been used for degradation of dioxins in waste sludge. This process requires extraction of the dioxins into a clean transparent solvent. Reaction products are dechlorinated phenolic materials including ethoxylated phenol. Use of UV photolysis on a liquid dioxin waste required six extractions to reduce the dioxin content from 343 ppm to 0.2 ppm. Photolysis of the extracted dioxin reduced dioxin level to less than 0.1 ppm after 20 hours. Overall destruction efficiency was 99.94 percent.

Applicability/Limitation: The inability of UV light to penetrate and destroy pollutants in soil or opaque solutions is a limitation of this approach. Photolysis can be enhanced by simultaneous introduction of ozone.

Status/Availability: Laboratory scale.

Manufacturer: SYNTEX

Users: _____

EPA Contact: Charles Rogers, (513) 569-7757

Technology: Vitrification

Brief Description: Large electrodes are inserted into soils containing significant levels of silicates. Graphite on the soil surface connects the electrodes. A high current of electricity passes through the electrodes and graphite. The heat causes a melt that gradually works downward through the soil. Some contaminant organics are volatilized and escape from the soil surface and may be collected by a vacuum system. Inorganics and some organics are trapped in the melt that as it cools becomes a form of obsidian or very strong glass.

Applicability/Limitation: Originally tested as a means of solidification/immobilization of low level radioactive metals. May also be useful for forming barrier walls (e.g., equivalent to slurry wall construction). This later use needs testing and evaluation to determine how uniform the wall would be and stability of the material over a period of time.

Status/Availability: _____

Manufacturer: Battelle Northwest has developed methods. Currently negotiating for commercial license by others.

Users: _____

EPA Contact: Donald Sanning, (513) 569-7875

Technology: Wet Air Oxidation

Brief Description: Uses elevated temperature and pressure to oxidize organics. The oxidation products stay in liquid as do the inorganics. The off-gas low in nitrogen oxides, sulfur oxides and particulates. Off-gas treatment may be used for hydrocarbon emissions. The advantages are that it is thermally self-sustaining, accepts waste with organic concentrations range between biological treatment and incineration, detoxifies priority pollutants and the products of oxidation and stay in the liquid phase. Wet air oxidation is particularly well suited for treating organic compounds in aqueous waste streams that are too dilute (<15 percent organics) to treat economically by incineration. Oxidation of the organic compounds occurs when the aqueous solution is heated to about 300°C and 137 atm in the presence of compressed air. Typically, 80 percent of the organic substances will be completely oxidized. The system can accommodate some partially halogenated compounds, but highly chlorinated species such as PCBs, are too stable for complete destruction without the addition of catalysts.

Applicability/Limitation: Used to treat aqueous waste streams with less than 5 percent organics and with some pesticides, phenolics and organic sulfur, cyanide wastewaters. It is not recommended for aromatic halogenated organics. This technology is not economical for dilute or concentrated wastes and it is not appropriate for solids or viscous liquids.

Status/Availability: Available at commercial scale.

Manufacturer: Zimpro, Inc., William Copa, (715) 359-7211
MODAR, Inc., (617) 655-7741
Vertech Treatment Systems, (303) 452-8800

Users: Casmalia Resources, 10-gpm demonstration unit.

EPA Contact: Harry M. Freeman, (513) 569-7529

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